Communication structures

Brian W. Smith

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Foreword

Today none of us can enjoy modern life even for a single day without maintaining communication with others or receiving information from radio and TV. Nevertheless, very few of us recognize that these modern conveniences are literally supported by structures properly designed, constructed and maintained for that particular purpose.

Although some of the tasks of terrestrial antennas have been taken over by celestial ones, more and more demands for transmission structures for local and ground communication have emerged in recent years. In Japan, for instance, the meteorological radar station on top of Mount Fuji, which had served for 35 years for weather forecasting, was dismantled and replaced by satellites in 1999. Meanwhile, the demand for a new Tokyo Tower for the ground digital communication networks, which may be twice as tall as the existing one, is now under discussion. A remarkably high structure like a TV tower often incorporates a viewing platform or restaurant for people at its top, and plays an important role as a tourist centre in the locality, too.

Brian Smith's book on communication structures is a thorough study of the technology of structures supporting communication systems for our society. It covers a very wide range of tower and mast structures, and looks at them from their history, forms, loads, analysis and design, codes and standards, fabrication and erection to their maintenance. The book also deals with access and safety of masts and towers, part of which has already been published within the IASS (International Association for Shell & Spatial Structures). I am sure that engineers who are working in the fields of design, analysis, fabrication and construction of masts and/or towers will accomplish their tasks with confidence by making good consultation with the book, which also contains comprehensive references for further study.

Brian Smith and I have been good friends for more than fifteen years, mainly through activities in the IASS. He has been a member of the IASS for a long time, and is currently one of the most active members of the IASS Executive Council. In 1997 he was conferred the IASS Tsuboi Award for his excellent joint paper on 'Simplified Dynamic analysis Methods for Guyed masts in Turbulent Winds' presented in the IASS Journal.

The IASS Working Group 4 for Masts and Towers, in which Brian has played the leading role, is the most animated working group in the Association. According to Brian he has received a great deal of help and advice from members of Working Group 4. On behalf of the IASS I am very proud of the Working Group as well as Brian himself, and would like to congratulate the Working Group and all the constituent members of the Group on the publication of this remarkable book.

Mamoru Kawaguchi, President of IASS, June, 2006

In preparing the report for the Executive Council meeting held in Montpellier, France on September 19, 2004, I was informed by Ulrik Støttrup-Andersen, Chairman of IASS Working Group 4 on Masts and Towers, that Brian Smith has, with the support of WG4, agreed to write a book on communication structures, and that IASS WG4 will act as the 'backing group'. By having the research results published in the form of a book, available in libraries and/or bookshelves is the highest status that can be achieved by an IASS working group and its members.

The importance of communication structures cannot be underestimated, as the failure of communication facilities can sometimes be quite destructive. One example was the malfunction of the communication facilities of a key station in the Kobe area of Japan immediately after the January 17, 1995 earthquake. This event was said to have prevented local governments knowing the level and scope of casualties caused by the disaster; as we know, this is crucial for the rescue of injured people from collapsed buildings in the first few critical hours.

On behalf of the IASS Technical Activities Committee, I would like to congratulate Brian for his endeavor in making this book a reality, and WG4 for their backing of such an endeavor. We believe that with this book, engineers and researchers working on communication structures and the like can benefit greatly from the huge amount of information provided.

Y.B. Yang, Chair, Technical Activities Committee, IASS. Taipei, Taiwan

Preface

Communication structures, in the modern sense – masts and towers – are now familiar to everybody as these structures are situated in the open landscape as well as in the middle of our cities. The tall masts and towers for broadcasting of radio and TV have gradually been accepted by the public, and now their focus is on the numerous number of smaller masts, towers and poles primarily used for mobile networks.

However, most of the general public are unaware of the engineering challenges and specialisms behind these common structures. They are not aware that 'a guyed-mast is one of the most complicated structures an engineer may be faced with' when driving by in their cars they see a 300 m broadcast mast; and nobody worries or gets nervous when they see on their TV screens the message 'temporary deterioration of the signal due to icing of the Emley Moor antenna'. It is of course wrong to say 'nobody' because there is a group of people – structural engineers, scientific researchers, mast and tower owners, antenna experts etc., which know and 'worry'. This group, heavily involved in the analysis, design, construction and operation of communication structures, have for a long time been discussing new developments, exchanging experiences, launching new designs, presenting numerous technical papers etc. worldwide, but have not until now systematically accumulated or gathered their knowledge into one work. This has led to a situation where analysis and design of communication structures has not appeared as part of the syllabus for structual engineers at technical unversities; and young engineers starting on their professional career have had no introduction to this field other than the experienced personnel in a company.

With this book, Brian W. Smith has covered the subject very effectively indeed; and this title will surely be invaluable not only for the new generation of engineers – whether they study at technical universities or they start their professional carreer in engineering practices, telecom organisations, with contractors or mast and tower fabricators, but also certainly for the established mast and tower experts. *Communication structures* is the first work of its kind, which in an instructive and clear way expounds the background of communication structures, taking into account all the issues involved in the analysis, design, fabrication, construction and maintenance. It is fully illustrated with excellent photographs and figures throughout and makes references to actual real-life constructions.

Brian W. Smith has been involved in the analysis and design of communication structures all of his professional life as a partner of Flint & Neill Partnership. He has been involved as the expert in all the British codes and standards directly related to masts and towers, and for those with influence on masts and towers. Internationally, Brian has been a very active member of the IASS (International Association for Shell and Spatial Structures) Working Group for Masts and Towers since its formation in 1969, and for ten years he was chairman of the group. Perhaps, most significant, is Brian's influence on the new common Eurocode for Towers and Masts, a work he has chaired and steered from its inception in 1993 to the final draft which was accepted unanimously by all the European states in 2003.

So when Brian gives credit for the book to the IASS WG 4 – it is for all members of this Group a great honour – an honour that none of us really deserve.

Ulrik Støttrup-Andersen, Chairman of IASS Working Group No. 4

Acknowledgements

The author has received a great deal of help and advice during the preparation of this manuscript. Working Group 4 (WG4) of the International Association of Shell and Spatial Structures (IASS) has provided both much of the source material as well as support for this venture. In particular, the following members of IASS WG4 have provided both advice and technical input to certain chapters as below:

Ondrej Fischer	(Chapter 11)
Duncan Gould	(Chapters 3, 7, 9, 13, 16 and Annex A)
Mark Grant	(Chapter 15)
Tony di Guglielmo	(Chapter 3)
Peter Heslop	(Chapters 2, 3)
Mark Malouf	(Chapter 14 and Annex A)
Don Marshall	(Chapter 16)
Ciro Martoni	(Chapter 10)
Ghyslaine McClure	(Chapter 18)
John Mearns	(Chapters 3, 16, 17)
Miroš Pirner	(Chapter 7)
Bruce Sparling	(Chapter 8)
John Wahba	(Chapter 14 and Annex A)
Simon Weisman	(Chapters 4, 5, 7, 8)
Geoff Wiskin	(Chapters 2, 3, 4)

In addition Ulrik Støttrup-Andersen (Chairman of IASS WG4) and Mogens Nielsen (Secretary of IASS WG4) reviewed and made valuable comments on all chapters. A full list of the current active members of IASS WG4 is given in Annex B.

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The support of the IASS through the President, Professor Mamoru Kawaguchi, and the Working Bureau is most gratefully acknowledged.

Finally, I would like to thank Flint & Neill Partnership for allowing me to prepare this document with their support, for my colleagues David MacKenzie and John Rees for reviewing the draft and providing valuable comments, and to Helen Cartwright for patiently typing the manuscript.

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Design considerations

3.1 General

Frequently the design and construction of the antenna support structure is, in terms of costs, a relatively small element in a complex project comprising access roads, buildings, site development, transmitters, monitoring equipment, power supplies, antennas and feeders. The project management team will need experts in each of these disciplines. However, the specification for each discipline is often produced independently, in spite of the inter-relationships with other disciplines. Generally the fundamental parameters are the available **frequency** at which the signal is transmitted, and the proposed **service area** (the population targeted to receive the service). A 'service area plan' is then developed, which explores available sites, the height of structure needed and the radiated power necessary to deliver the signal. This proposed radiated power, in turn, defines the options for the physical size and disposition of the antenna and feeders, which in their turn define the weights and wind resistance to be carried by the structure. These data are then incorporated into the design brief and passed to the structural engineer.

Frequently the structural engineer is unaware of possible alternatives that may provide the client with a more economical solution. For example, in broadcasting the transmitted signal strength or effective radiated power (erp) is a function of the transmitter power and the gain of the antenna array. By increasing the transmitter power the gain (and thus the length of the antenna aperture) can be reduced, saving antenna cost and significantly reducing the structural loading. Unfortunately this increases the initial cost of the transmitters and also the power consumption and running costs. Broadcast project engineers hence have to try to optimize the combination of transmitter and antenna costs but, unless they are alerted by the structural designer, rarely consider the potential reduction in structure cost which a smaller antenna might permit. For example, a slight reduction in antenna loading might allow a standard 'off-the-shelf' structure to be used rather than a more costly 'special' design. More commonly on existing structures, a smaller antenna may be possible without the need for structural strengthening whereas a larger antenna could necessitate significant strengthening.

3.2 Choice of site

The selection of the site must take into account:

- The area to be served by the installation; clearly this is dependent on the type of service to be provided – cellular phone, television, microwave networks, etc. – and on the density of population in that area. This will have economic and environmental implications.
- The distribution of the population in that area; this could affect the directionality needed of the antenna system and, possibly, the orientation in plan of the structure itself (see section 3.6).
- The general nature of the terrain; this will affect the height of the structure (see below).
- The presence, or otherwise, of high ground in the locality; this can again alter the height of the structure, and the viability of sites in the shadow of the high ground.
- The radiation pattern from the proposed antenna; for example for TV broadcasting whether the horizontal pattern of radiation should be omnidirectional or shaped to provide increased power towards more distant parts of the served area. On occasions the pattern needs to be shaped to protect an adjacent service on the same frequency.
- For telecommunication structures used for mobile phone services, the principal concern is the aesthetics of the structures, particularly in suburban areas. Novel lattice structures are often needed to placate local Authority demands and residents' concerns (see section 3.5).

The final choice is invariably a compromise between economics of the proposed service and the demands of other services in different frequency bands that could enable co-siting to be considered.

The range of a broadcast signal, and hence the service area covered, is governed not only by the erp from the antenna but also by a combination of the height of the antenna and the nature of the terrain and the

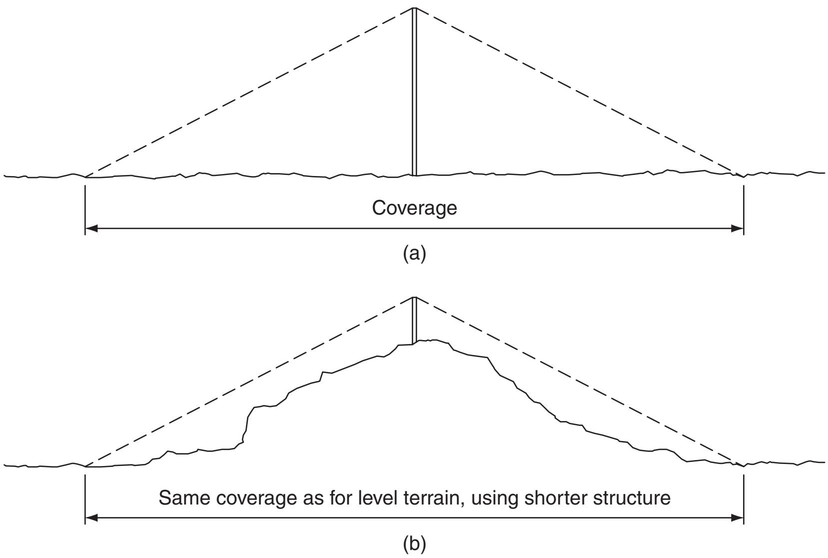

Fig. 3.1 Aerial coverage

broadcast frequency. The higher the broadcast frequency the more the service area will be restricted to line of sight from the antenna.

For TV and FM radio the height of the antenna above the mean ground between the transmitter and receiver is a crucial factor in determining the strength of the signal received. This height depends partly on the elevation of the chosen site, and partly on the height of the antenna above the site ground level. Generally speaking, high supports are required when the terrain is level (effective site height small) (see Fig. 3.1(a)), and in such cases conditions will normally favour the erection of high structures, whereas in mountainous regions, where the elevation of the site is significant but erection conditions difficult, lower supports can be used (see Fig. 3.1(b)). This is well illustrated by comparing Denmark and the Netherlands where mean site elevations are practically zero and antenna structures over 250 m high are common, with Spain and Portugal where sites often exceed 500 m in elevation and the average structure is some 60 m high.

The broadcast frequency also has a significant influence on the range of the signal. Lower frequency signals have greater ability to diffract around obstructions and hence the amount of shadowing from a fixed source increases rapidly with frequency (see Fig. 3.2).

Ideally, however, the transmitting site should provide an unobstructed line-of-sight over the area to be covered, particularly for UHF services.

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